HIGH RESOLUTION X-RAY CT IMAGES OF CHONDRITES AND CHONDRULES, AND THEIR THREE-DIMENSIONAL STRUCTURES. A. Tsuchiyama[1], M. Kondo[1], H. Hirai[2], and A. Koishikawa[2], [1]Department of Earth and Space Science, Osaka University, 1-16, Machikaneyama, Toyonaka, Osaka 560, JAPAN (akira• @ess.sci.osaka-u.ac.jp), [2]Nittetsu Elex Co., Ltd, 4-152, Midorimachi, Sakai, Osaka 590, JAPAN.

Images of Moorabie (L3), Allende (CV3), and chondrules removed from Allende were obtained by high resolution X-ray computer tomography (CT) with a spacial resolution of a few mm. Fe-Ni alloy, troilite, and silicates can be distinguished, and chondrules, CAI's, and matrix can be recognized. Many euhedral crystals, probably olivine, were identified in a chondrule, suggesting that the chondrule has a porphyritic texture. In addition to minerals or their assemblages, holes can be also identified, and this shows potential to analyze primordial solar nebula gas trapped in chondrules. Three-dimensional structures were reconstructed from successive images. In the porphyritic chondrule, the shapes of the holes are irregular three-dimensionally, and similar to those formed by visco-elastic fingering. This may suggest that the holes were formed by shrinkage of the melt by solidification.

Introduction. Textures of meteorites are generally studied by making thin sections and analyzing using an optical microscope, SEM and EPMA. X-ray computed tomography (CT) may give textural information without breaking samples, and provide three-dimensional structures from successive images. In the present study, X-ray CT images of chondrites and chondrules were obtained using a high resolution X-ray CT scanner to evaluate what features can be identified in the X-ray CT images. Finally, three-dimensional structures were reconstructed by taking successive images with a computer image processing technique.

Experiments. We used a so-called third generation X-ray CT scanner of Nittetsu Elex Co., Ltd. [1], which has a micro-focus X-ray source (3 mm; open type with a tungsten target) to give a spacial resolution of several microns, and makes it possible to take images by changing the magnification for small samples such as chondrules. The accelerating voltage and tube current ranged from 90 to 120 kV and from 0.06 to 0.07 mA, respectively. Images of cross sections were constructed with a filtered back projection method (FBP) by rotating samples. High resolution X-ray CT images were obtained by a linear detector made of 2048 CCD elements [2]. Successive images for three-dimensional structures were obtained simultaneously by using an area sensor (512x512 channelling plate). The Moorabie (L3) and Allende (CV3) meteorites were used as representative samples of ordinary and carbonaceous unequilibrated chondrites, respectively. They were cut into cylinders of 8 mm and 10 mm in diameter, respectively, to remove artifacts in their X-ray CT images. After imaging, the samples were cut very carefully to obtain the surfaces which represent the same positions as slices of their X-ray CT images, and examined by an optical microscope, an SEM/EPMA, and an X-ray microscope. Chondrules removed from Allende meteorite by the freeze-thaw method were also studied. Slice thickness was changed from 10 to 50 mm to obtain better contrast of images.

Results and discussions. In X-ray CT images, Fe-Ni alloy, troilite, and silicates can be distinguished clearly, and chondrules can be resolved from their Fe-rich rims in Moorabie meteorite. In Allende Fe-Ni alloy, pentlandite, and silicates can be distinguished, and chondrules, CAI's, and matrix can be recognized. In chondrules, because of the large magnification of the samples, high spacial resolution was obtained, and thus smaller structures can be seen. Three-dimensional structures of a chondrule constructed from 104 images is shown in Fig.1(a). Many euhedral crystals, possibly olivine, were identified probably due to FeO-rich rims, suggesting that the chondrule has a porphyritic texture. In addition, dark portions which may correspond to holes are seen inside the chondrule. Similar structures in some chondrules were also found in the CT-image of Allende, and they were confirmed as holes [2]. The presence of holes cannot be recognized by conventional thin sectioning technique alone because holes can be also formed during thin sectioning processes. Fig.1(b) shows a computer graphics where holes in the chondrule are shown exclusively. The shapes of the holes are irregular, and similar to those formed by visco-elastic fingering [3]. There are three possibilities as origin of holes in chondrules; (1) during a cooling stage of chondrule formation, the outer portion of a chondrule melt droplet was solidified first, and then holes were formed due to shrinkage of the inner portion by further solidification, (2) when a chondrule droplet was formed by heating of a dust ball, the surrounding gas was trapped into the chondrules, or (3) bubbles were formed by boiling when the vapor pressure of a volatile element in a chondrule droplet became higher than the nebula pressure. The present results indicate the possibility of (1). A spherical hole is also observed in another chondrule [2] indicating the possibility of (2) or (3). This type of chondrule can retain primordial solar nebula gas.

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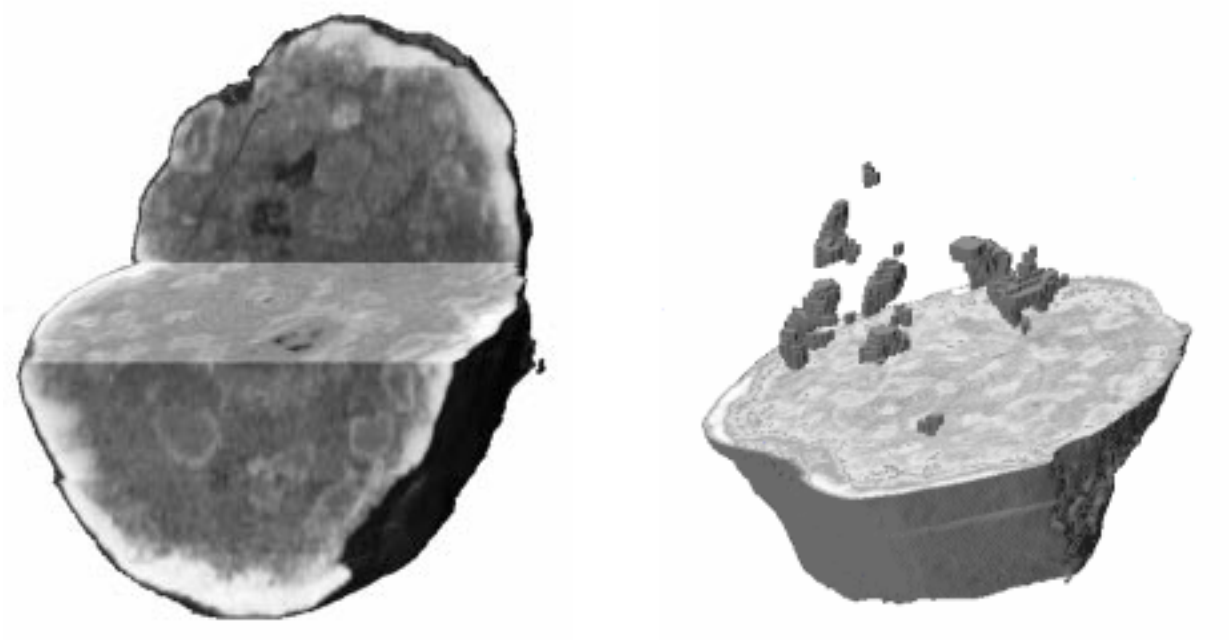

(a) (b)

Figure 1. Three-dimensional structure of a chondrule removed from Allende (about 2.5 mm in diameter). This was reconstructed from 104 X-ray CT images with each 17 mm slice thickness and 5.6 mm interval. The spacial resolution determined by the magnification and the number of the sensor array (about 7 10,) is smaller than the slice thickness. The chondrule is elongated vertically in the graphics due to the difference of the vertical and horizontal scales. (a) A computer graphics showing difference of X-ray adsorption. Brighter portions have stronger X-ray absorption. Chondrule rim probably composed of a FeS-silicate mixture, silicate phenocrysts probably olivine crystals bounded by FeO-rich rims, and dark parts probably holes are seen. Concentric ring patterns are artifacts. (b) A computer graphics where the “holes” are shown exclusively.